91-92

aculteit der Economische Wetenschappen en Econometrie

Serie Research Memoranda

Modelling Ecologically Sustainable Economic Development in a Region: A Case Study in the Netherlands

J.C.J.M. van den Bergh
P. Nijkamp

Research Memorandum 1991 - 92
december 1991

vrije Universiteit *amsterdam*

ABSTRACT.

This paper focuses attention on the relevance of the notion of sustainable development in a regional context and the use of models for regional sustainable development policy. The paper discusses first the notion of sustainable development by linking socio-economic and ecological elements. Time and space prove to be important dimensions of sustainable development. In a spatial context, an often neglected but relevant concept is that of regional sustainable development (RSD). Its relationship with both the global concept of sustainable development and sustainable use of resources is discussed. Next, we focus on the use of models for sustainable development in a regional context. All such models integrate economy and ecology: a description of economic processes, ecological processes and their interactions; and an inclusion of socio-economic and ecological indicators in the policy evaluation. Only dynamic models are considered, as they are regarded to be the most relevant class for tracing sustainable development. It is argued that scenario and simulation models are most appropriate on a regional level, as here the level of detail of describing economics and ecology (and their interactions), including their policy relevance, is fairly balanced. Finally, a case study is presented for the Peel region, an agricultural area in the Netherlands, where presently agriculture causes considerable damage to groundwater, forests, and protected fen areas due to intensive cattle farming, irrigation and drainage. Several relevant development scenarios for RSD planning are developed, and the model analyses for each of them are reviewed from the viewpoint of RSD.

1. INTRODUCTION.

In recent years the concept of sustainable development (abbreviated as SD) has intensively been discussed from a global perspective (see Brown et al., 1987). Modelling SD has up till now not been very successful, as it appeared to be very difficult to design empirically-oriented global policy models. The aim of this paper is to investigate the relevance of this concept in the framework of the concept of SD on the basis of an operational policy model focusing attention on a meso (i.e. regional) system. Hence, in this paper the concept of regional sustainable development (abbreviated as RSD) will be introduced and outlined. In this context, the attention will be directed towards a discussion of the characteristics of models that can be used to substantiate SD and RSD notions, not only in conceptual but also in operational terms. The paper is organized as follows. In the next section SD will concisely be discussed, followed by a more focused approach to sustainable development on a regional scale. Next, in section 3 we will give a discussion and clarification of the related concept of a regional resource base, while section 4 will then deal with features of planning models for SD and RSD. Finally, an elaborate regional economic planning model related to sustainable development issues in one of the regions in the Netherlands is presented; these modelling experiments use simulation techniques for the analysis of RSD. The paper is concluded with some retrospective and prospective remarks on RSD.

2. GLOBAL SUSTAINABLE DEVELOPMENT AND REGIONAL SUSTAINABLE DEVELOPMENT.

The concept of SD is - particularly since the publication of the Brundtland report (WCED, 1987) - increasingly referred to in integrated economic-ecological analyses and models. This concept reflects a compromise between the aim of economic growth and concern for the environment, seen from a long-term perspective. It recognizes the goal of survival of the human species, realization of an acceptable quality of life for each individual in present and future generations, preservation of diversity and quality in the natural environment, and wise management of natural resources and ecosystems (see for a diversity of approaches e.g., Clark and Munn, 1986; Tolba, 1987; Opschoor, 1987; Goodland and Ledec, 1987; Redclift, 1987; Turner, 1988; Collard et al., 1988; Pezzey, 1989; Archibugi and Nijkamp, 1989; de Vries, 1989; NAVF, 1990; Simonis, 1990; Daly, 1990; and Hueting, 1990).

'Sustainability' is a general term indicating that the necessary conditions for the existence of some dynamic phenomenon are permanently satisfied. The more restricted - but also more focused - concept of ecologically sustainable economic development presupposes a time pattern and composition of economic activities which ensure the achievement of a sufficient (average) income level for all relevant generations and which also lead to a minimum level of non-priced social costs (or negative externalities) for the environment, while all aspects of this development are in the long run fulfilled by a sufficient availability of natural resources and assimilative capacities of the environment (the necessary dynamic conditions). Strategies for such sustainable development may include substitution of a harmful type of resource, production technique or consumption good for another, or a more intensive use of certain environment-friendly renewable resources. How to use and manage a variety of resources depends on their specific features, their function in large-scale natural processes and ecosystems, and their links with basic human needs. Clearly, the operationalisation of SD in a concrete policy setting is fraught with many problems, comparable to that of the concepts of welfare and progress.

Many global environmental problems (e.g., ozonization) are caused by the sum total of a great many small-scale and local or regional activities. Moreover, the effects of environmental changes (e.g., climate change) are usually experienced at a local or regional level. By choosing a regional angle for the analysis of SD, the probability of choosing more reliable and measurable indicators for practical planning strategies is increasing. In addition, the identification of concrete development scenarios, policy objectives and measures can much easier be achieved. Thus, the focus on a region offers perspectives for operationalizing the general - and often fuzzy - concept of SD.

RSD may be regarded as a translation and operalisation of the global concept of SD towards the regional level. However, a region cannot be regarded in isolation but is part of an open system, so that we must consider its development in relation to interactions with other regions and their respective developments. One may interpret RSD as sustainable development in an open system that fulfils two conditions: (1) it should not be in contrast with SD at a supra-regional level; (2) it should ensure for the regional population an acceptable level of welfare over a sufficient long time horizon. The first feature ensures that RSD does not conflict with the welfare level of other regions (see van den Bergh and Soeteman, 1990).

The first difference between a closed and an open system, relevant to the distinction between SD and RSD, is the presence of cross-boundary flows. They can be distinguished into incoming, outgoing and through flows. To support RSD, one might require no (or a minimum of) cross-boundary flows as an objective. Alternatively, the existence of closed cycles of interregional materials flows, or ingoing and outgoing flows that do not disturb the regional stocks of materials - in both an ecological and economic sense - may be desired above internal flows only. A second element important for the distinction between RSD and SD is the presence of external determinants of regional development (see e.g., Siebert, 1969). Examples of external factors of regional development are external sources of income and supply of inputs. All external factors of regional development are exogenously determined from the viewpoint of the region. All external determinants can in one way or another be derived from the crossboundary flows of the region, i.e., in order to be effective external determinants depend on economic and ecological flows. For instance, many flows arise from differences between values of identical internal and external variables.

In order to provide a concrete approach to RSD - one that is also more relevant in an operational planning context - it is meaningful to introduce also the concept of sustainable resource use. Sustainable use of - a renewable - resource means that the rate of use is not higher than the controlled or natural regeneration rate of the resource. Sustainable use allows for stock levels and regeneration rates to be maintained, so that it is possible to enjoy a certain amount of resource goods or services for a long period of time. RSD may provide an appropriate bridge between the clear but rather rigid objective of sustainable resource use and the more vague but flexible objective of sustainable development. Sustainable use of a region's stock of resources may be regarded as an important necessary - though not sufficient - condition for RSD. Such a conservation strategy is essentially a risk-avoiding strategy. If a stock of renewable resources is wisely used, it may generate a flow of materials and/or services for an unlimited period of time. If this flow is sufficient for generating an acceptable welfare level for the regional population ('sustainable welfare'), it is clear that one should aim at a balanced use of the regional resource. Thus resource management is a critical variable, as overexploitation or extinction of a resource is in most cases an irreversible process.

Three methodological steps can be distinguished in the analysis of RSD. A first step towards RSD analysis is a **stock-taking of the characteristics and internal structure** of a region, its interactions with other regions, and the relationships of regional processes with relevant external phenomena. Based on this information, one may arrive at a more clear view on the potentials and constraints for the region's future development.

A second step in RSD analysis involves the **assessment of both feasible and uncertain developments** that will cause a significant deviation from the extrapolated course. They include governmental policies, expected technological developments, investment programmes and conservation programmes. The assessment of future developments relevant to the regional system's development should also include extra-regional developments, especially with respect to resource availability and pollution emissions.

A third step in RSD analysis is the **evaluation of different development paths** for the regional system under consideration. In order to conduct such an effort the behaviour of a set of performance indicators (or critical success factors) should be compared with critical threshold values. These are usually identified on the basis of political, socio-economic and ecological information and arguments. Two types of indicators may be distinguished in the evaluation of sustainable development of a region. In the first place, *indicators may provide the necessary information for judging the desirability of a state* of the system at a given point in time; these are indicators for a static evaluation of welfare (e.g., levels). Secondly, indicators of change may be distinguished which provide information about the potentials and constraints for a dynamic evaluation of future developments of the regional system (e.g., rates of change).

It is of course clear that a great many types of regions can be distinguished ranging from urban regions, industrial areas, agricultural areas, environmentally protected areas, islands, recreational areas, etc. It is impossible to classify in general a set of regions according to specific features of RSD. Only when the regional characteristics are known in more detail, it is possible to typify RSD in that specific region. For this reason modelling RSD on the basis of case studies for various types of regions is essential. An illustration of such a modelling exercise is given in section 5.

3. INTERACTIONS BETWEEN A REGIONAL RESOURCE BASE AND ECONOMIC ACTIVITIES.

Regional development is by various authors assumed to be critically dependent on the regional supply of natural resources (e.g., Howe, 1979 and 1987; Miernyk, 1982; Siebert, 1984; Neary and van Wijnbergen, 1985; Walker, 1987). A resource base is the complex of resources and their regenerative support systems that are critically important for regional welfare. Furthermore, it has been argued that especially regions with energy resources and agriculture may exhibit nowadays a strong growth in income levels, as opposed to regions dependent on external energy sources, which experienced rapid growth in the past as a result of low energy prices (see e.g. Miernyk, 1982). But it is clear that - in addition to energy - also other factors may be of critical importance for a region's development. Various types of regional economic dependence on natural resources can be distinguished:

- direct dependence on economic activities; the natural resources may act either as a supplier of cheap productive inputs for economic activities, or provide the necessary conditions for specific agricultural or recreational activities; moreover, the environmental capacity as a sink of waste materials and pollution may also act as a restrictive factor to economic activity;
- export of resources as a main source of income for the region; in some regions a (sharp) rise in per capita income levels is sometimes clearly caused by such a relationship, e.g., in oil-exporting countries, in tourist areas, or in coal mining regions.
- satisfaction of local physical needs by local activities based on the available regional resources, e.g. in agriculture, energy and water utilities, and industries using inputs from forests, mineral mines and ore mines;
- impact of a regional resource depending sector on the general level of regional economic activity; clearly, the development of a resource sector may generate shifts in sector allocation, income levels, and distribution and exchange rates (see e.g., Siebert 1984).

The potential of the management and use of a regional resource base to realize RSD depends on the quantity and quality of the resources and their respective characteristics. Such characteristics refer to questions whether a resource can be exhausted, is potentially renewable, multifunctional, a private or a public good, or whether it forms part of a closed natural subsystem within the region. It is clear that there may be conflicts between various uses of the resource base, for which purpose also multi-objective programming methods may be useful (see Nijkamp et al., 1990).

It should also be added that in general resource uses are diverse. First, one has to distinguish between a situation of single and multiple use. Several types of interactions - usually subdivided into extractive and non-extractive uses - between a regional economic system and a resource system can be distinguished: (1) extraction of non-renewable natural resources, e.g., minerals and fossil fuels; (2) extraction of abiotic renewable natural resources, e.g., groundwater; (3) extraction of biotic renewable natural resources, e.g., fish and timber; (4) agricultural activities affecting groundwater, e.g., fertilization, irrigation, drainage; (5) agricultural activities affecting soils, e.g., fertilization, ploughing, grazing, irrigation, and drainage; (6) use of terrestrial and aquatic ecosystems for recreational purposes; (7) use of land, and building infrastructure; (8) emission of pollutants and waste disposal; (9) ecological disturbance; and (10) management of regional ecosystems, (11) conservation of terrestrial and aquatic ecosystems, and (12) insertive uses like planting trees. Several of these types of resource uses will also be included in the model designed in section 5 of this paper.

Before presenting this model, we will outline some features of models for analyzing RSD.

4. THE USE OF MODELS FOR REGIONAL SUSTAINABLE DEVELOPMENT.

A main advantage of using models in the context of SD is the fact that they can replicate part of the complicated nature of real-world processes. An important question regarding the use of models for SD is the choice of specific models for covering SD issues or for tracing SD trajectories. Models can summarize many valuable theoretical and empirical insights, while they can be tested and improved. Especially the complicated pattern of interactions within and between economic and ecological processes calls usually for an accurate and detailed description. Indirect and feedback, non-linear, time-delayed and other kinds of relationships can be dealt with most appropriately in a formal modelling framework (see Lonergan, 1981; and Brouwer and Nijkamp, 1988). Simulation models are especially suitable for incorporating many theoretically and empirically obtained results of partial studies. Moreover, inclusion of uncertainty in the specification and use of models may lead to quantitative, comparable and more precise estimations than an intuitive reflection on relationships between uncertainty and indicator values.

The most significant features of models for SD, distinguishing them from other models used for analyzing environmental problems are (see also Pezzey, 1989; Barbier, 1989; de Vries, 1989; van den Bergh and Nijkamp, 1990):

- a complete - as opposed to a partial - approach, i.e., taking all relevant activities and sub-systems into account;
- a module that describes the dynamics of resource bases and ecosystems, so that the indirect effects and consequences of specific economic developments for natural environments can be traced;
- a feedback of ecological impacts of economic activity towards the economic system; the ecosystem provides the economic system with dynamic physical constraints and potentials; (non-physical) feedbacks from ecological indicators to economic behaviour might be considered as well.
- a long term perspective allowing for qualitative change and consideration of long-term or intergenerational distributions;
- inclusion of material (physical) and non-material elements of the regional resource base; this means that an evaluation has to be made of both production and welfare derived from the use of the natural environment.

To provide an overview of existing models for RSD is not very easy, as the number of attempts is scattered and rare. The most important reason for this is that it is essential that such models combine a complete (general) approach, a long term viewpoint and the integration of economic and ecological processes, as well as of economic and environmental policies (as is clear from the above features). We will first take a concise look at some related modelling efforts from the viewpoint of the objective of the present study.

A first formal approach to integrate economics and ecology is the input-output matrix approach proposed by Isard (1972). Braat and van Lierop (1987, chapter 4) distinguish between three approaches to use models for integration. First, 'compartment modeling' approach uses models developed independently in separate disciplines to exchange outputs after adequate transformations have been realized. Secondly, systems theory approach aims for one (holistic) model (some of the global models; see for an overview Meadows et al., 1982; for simple approaches see Odum, 1987), so that consistency between the descriptions of the economic and ecological processes is ensured (see Bennet and Chorley, 1978). Other approaches in this class include complex models with a short or medium term and partial focus (Holling, 1978), while sometimes also computer simulation techniques in combination with optimization techniques are used(for instance, Lonergan, 1981). The third approach is to expand a mono-disciplinary model in order to include descriptions of other disciplinary areas, for instance, analytical models of economic growth combined with pollution and/or resources (see for an overview Kamien and Schwartz, 1982), or dynamic models of sector-resource interactions (see Clark, 1976; and Walters, 1986). Most (pre-)operational models labeled as economic-ecological or economic-environmental are only linking a description of one or more processes from one system (the economy or the natural environment) with one or more variables in the other, so that often no feedback occurs. These types of models are often based on an input-output framework proposed by Leontief and Ford (1972) (see for an overview, Briassoulis, 1986). Their static character is however very limitative from the viewpoint of SD analysis, and hence we have to focus attention on dynamic modelling approaches. In particular, the variables are usually not more than given inputs (e.g., resources) to or generated outputs by such a model. The inputs or outputs may be used in combination with constraints and objectives, so that these models can be extended to multi-objective or linear programming models (see Hafkamp, 1984). Such models are however incomplete for our purposes, since they integrate economics and natural environment as processes with variables instead of processes with processes. This characteristic, often combined with a linear structure, provides such models at best a short or medium term character.

Dynamic (regional) models may be subdivided into programming, simulation and analytical models. In the context of our analysis simulation models seem most suitable because of the following characteristics (see Guetzkow, Kotler and Schultz, 1972; Frenkiel and Goodall, 1978):

- a detailed systems description is possible, limited only by the availability of data and computer capacity;
- a subdivision of the whole model into modules makes a complicated model easier to work with (design and adjustment); modules may be related to specific ecosystems, economic sectors, factor markets, decision-making units, population and spatial subdivisions;
- interactions between multiple regions can also be dealt with by representing each of them in separate modules;
- nonlinear, dynamic and stochastic specifications may be included;
- one may combine causal and correlative relationships; and econometric, input-output or stock-flow specifications can be used together;
- they can be used for policy analysis, e.g. based on scenario experiments.

Phenomena with a long-term evolution may be included in two ways. First, one may aim at an endogenous representation of the long term driving forces, such as technical progress. Secondly, one may design scenarios including exogenous, policy and behavioural patterns over time or shocks at points in time. In our case study we have chosen for the latter option.

In order to be able to integrate potential economic and ecological submodels - i.e., to provide for an interactive module -, they should be consistent with one another in terms of geographical coverage and level of aggregation (see also Brouwer, 1987; Braat and van Lierop, 1987). In general, the level of aggregation in a model should be consistent with the objectives of using that model. The complexity of models for RSD tends to be high for the following reasons: (i) inclusion of three types of relationships (economic, ecological and interactions); (ii) a high level of completeness of description of the economic and ecological system (economic system: sectoral division, production, investment, consumption, markets, government, financial and material balances, etc.; ecological system: foodchain processes, flows of water, nutrients, and energy through the systems, material balances, etc.); (iii) the presence of exogenous variables (in combination with scenarios) or processes for the representation of long term dynamics; (iv) disaggregate descriptions (since behavioural, physical, biological and chemical processes can be described in a less abstract manner at a low level of aggregation; see Patten, 1971-1976).

In order to illustrate the relevance of the RSD concept and of the above remarks on RSD modeling, we will present in the next section the structure and some results of an RSD model developed for policy analysis of an area, viz. the Peel, in the Netherlands.

5. A CASE STUDY: THE PEEL REGION IN THE NETHERLANDS.

The Peel area in the south-east of the Netherlands has been selected as a test case for RSD modelling because of its problematic interactions between the natural resource base and economic activities (see van den Bergh et al., 1988). Two natural fen areas (de Groote Peel and Maria Peel) are situated in an area in which intensive cattle farming and mixed agriculture are the dominant users of the land. The study focuses on the use of forests, natural areas and groundwater. Drainage of the land has been instrumental to the historical development of the region. Extensive drainage still occurs each spring, lowering the water level so that machines can work on the land. During summer, potential (as well as actual) shortfalls in soil moisture are circumvented by irrigation sprinklers; water is derived from groundwater reserves. Recharge of groundwater reserves may be constrained by spring drainage, yet the reserves are used intensively during the summer. There are hence various questions and conflicting issues regarding the 'sustainability' of such practices. Economic activities which are directly dependent on the groundwater resource include agriculture and municipal water supply. Other activities in the region are timber production, recreation and nature conservation. Especially agriculture is at the present significantly contributing to regional income. Conflicts between recreation, economy and the environment have increasingly emerged in this area, and therefore it may serve as an interesting pilot study for an RSD analysis.

The natural resources in the region are the starting points of our analysis (see section 3). Economic activities are taken into account insofar as they influence (or are influenced by) these resources. Consequently, the regional boundaries were primarily determined by ecological and geographical criteria, based on the groundwater basin around the Peel-fen reserves (so-called ecohydrological districts; see Braat and van Amstel, 1988).

The main structure (i.e., the modular design) of the RSD model for the Peel region is given in Figure 1. The renewable natural resources central in our analysis are groundwater, forests and natural vegetation. The issues associated with these may be summarized as follows:

1. high water tables, sandy soil and nutrient-poor conditions have led to the development of unique ecological communities;

2. widespread drainage of the land and multiple use of the groundwater resource (for irrigation as well as municipal supply) has lowered the water tables;
3. agricultural activities, with intensive use of fertilizer and with increasing manure production, are causing nitrate enrichment of the groundwater, with impacts on the remnant vegetation as well as decreasing suitability for human consumption;
4. air pollution is also causing acidification of soils, with impacts on the natural vegetation as well as on forests.

For some production activities a further subdivision is useful. For example, timber production is based on two tree species - pines and Douglas fir, both of which are produced in plantations. Agriculture comprises the rearing of livestock (cattle, pigs and poultry), and crop cultivation (for livestock and human consumption); livestock rearing can be either intensive (e.g., bioindustry for meat and egg products) or extensive (e.g., dairy and meat).

The spatial distribution of activities in the region also affects their interactions and relationships with resources. For example, groundwater extraction for agriculture is shallow and widespread, whereas that for municipal supply occurs at a small number of sites and involves deeper extraction. The main regional cross-boundary flows which affect regional processes are visitors of the natural areas, inflow and outflow of air pollution, and export of agricultural and forestry products.

The central focus of this study is the use of the region's natural resource base by the region's economic activities. Multiple use is a prominent feature and a source of conflict, since allocation of a scarce resource among users involves trade-offs. For example, economic activities are not the only user of groundwater, while groundwater is also crucial for the regeneration of wetland communities.

The use of the Peel's natural resources as economic goods includes: extraction of groundwater for drinking water; groundwater for irrigation by agriculture; timber in forestry; and soil for growing crops. The use of the Peel's natural resources as services includes: natural areas for recreation and nature conservation; land for disposal of surplus manure; and air, soil and groundwater as deposits of ammonia and nitrate from manure.

The analysis of regional system interactions in this area has resulted in a dynamic simulation model programmed in STELLA (Richmond et al., 1987). The model is exploratory in nature. It takes a long-term viewpoint by way of long-term scenarios and policies. It includes descriptions of interactions between the economic activities and the relevant environmental processes. The sub-modules describe groundwater, nitrates, forestry and natural vegetation, agriculture (manure), and regional economic activities. The submodule which describes the economic activity accounts profits over time for each sector, on the basis of developments of quantities, costs, prices and technology. The time paths for quantities (number of products actually sold, or services actually delivered, measured in relevant units for each respective sector) is for most sectors based on changes in production capacity, except for recreation, where demand for recreational activity determines the quantity. The development of the economic system is to a large extent determined by exogenous variables, for which time paths were chosen in each development scenario. Models that include many interactions between sectors (e.g., interindustry supply, or competition on factor and final markets) usually have an economy-wide rather than a regional orientation (cf. Vincent, 1982). The interrelationships between the modules are listed in Figure 1 (see for a more detailed description van den Bergh et al., 1989). A condense mathematical formulation of the model can be found in the annex.

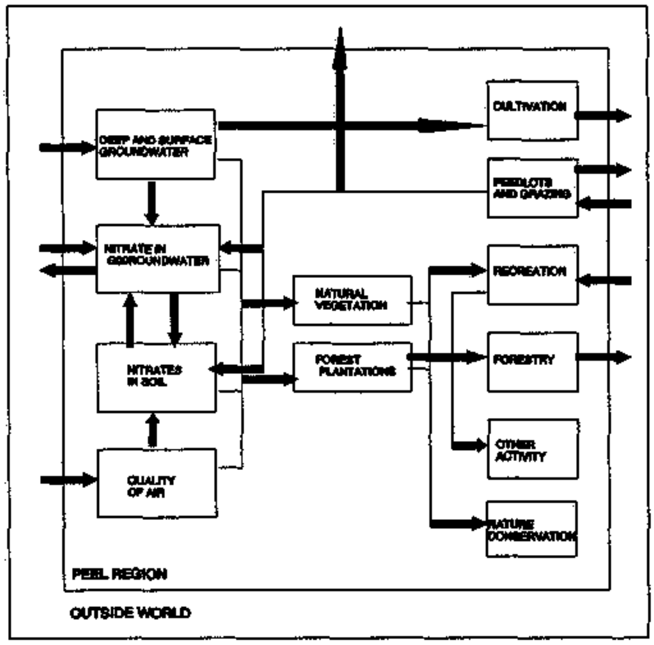

Figure 1: Structure of the economic-ecological model for the Peel region.

The indicator variables chosen for the assessment of RSD are listed in Table 1. The indicator for nature conservation value is based on areas of vegetation. Recreational attractiveness is based on economic facilities, natural amenities, and disservices (arising from economic activities). In the table, stock variables are chosen to serve as dynamic indicators. This means that they indicate in what direction the dynamic path of the resource base is moving. These stock variables may be replaced by their associated rates of change in the stock variables. But if complete dynamic patterns (i.e., for the whole period under consideration) are shown, the stock variables provide all information about the rates of change in their levels and in addition provide information on actual levels at each point in time as well.

INDICATORS FOR RSD		Indicator	Units of measurement	Graph and number	Symbol in model[1]
physical	1.	Concentration of nitrates in deep groundwater	kg/ML	a 1	ConcN_deep
	2.	The total ammonia release from manure	kg	a 2	N3
	3.	The soil pH	index (0-12)	a 3	pH_soil
	4.	The volume of surface groundwater	ML	a 4	Sg_surf
	5.	The volume of deep groundwater	ML	c 1	Sg_deep
	6.	The air quality	index	c 3	Qair
vegetational	7.	Stock of Alders	m3	b 1	VOL_A
	8.	Stock of Douglas Pines	m3	b 2	VOL_P
	9.	Stock of Wet Heathland	m3	b 3	VOL_Wh
	10.	Stock of Grass	m3	b 4	VOL_Gr
economic	11.	The nature conservation value	index	c 2	X_n
	12.	The total value added	Dutch Guilders	c 4	Addval_tot

Table 1: Indicators for RSD in the Peel area.

For the evaluation of long-run effects we will use policy scenario experiments in combination with simulation modelling. The choice of these scenarios is to a large extent based on current environmental, agricultural and regional development policy issues in the Netherlands, following the world-wide discussion on sustainable development after the publication of the Brundtland report.

Each scenario that is used for a simulation run has effects that will be evaluated regarding their RSD via the indicators listed in table 1. The last column shows which curves in which graphs represent these indicators. Effects may be compared to standards, and then lead to inferences about acceptation or rejection of the relevance of the scenario used for RSD. The scenarios are determined by choices for both exogenous and management (or control) variables. To limit the number of scenarios some plausible developments consisting of a set of related changes in variables have been identified. The time horizon of the scenarios is 50 years with base year 1980/81,

[1] See the annex for the definition of variables.

while the time resolution is given in years. The model has been run for a set of 4 different - partly contrasting, partly complementary - scenarios mentioned hereafter. Each scenario description is followed by a concise evaluation of the time paths of indicators.

(1) **Present development.**

The assumptions concerning future developments are here as follows following. The stock of grazing cattle declines from 1980 to 1985 and remains constant during the rest of the simulation period. The stock of feedlot cattle will increase with 10 percent each period of twenty years. Population will increase with 9,000 per decade. Imported nitrogen and sulphuroxides emissions decline. NOx emissions decrease with 30% and SO2 emissions with 45% after 15 years. The results in Figures 2a-c indicate that very slowly initially value added decreases, which is the net result from decreasing benefits of grazing cattle, cultivated land and recreational revenues, and increasing benefits from intensive cattle breeding. Agricultural land is less productive as a result of decreasing surface groundwater levels. There is a trend of grassification of heathland. Ammonia and nitrate emissions increase slowly and the concentration of nitrates in deep groundwater stocks is slowly rising.

(2) **No import of SO2 and NOx.**

This scenario is based on the same assumptions as the first scenario except for import of SO2 and NOx. It is now assumed that their emissions start to decrease after 15 years as a result of foreign policies, and reach a zero level after 50 years. The results in figures 3a-c show that - compared to the first scenario - pH and air quality improve drastically, so that the openness in an ecological sense of this region is very sensitive. The trend of grassification of heathland is reversed. Forest benefits from improvements in Douglas and Alders cause value added for the region as a whole to increase.

(3) **Environmental policy.**

Based on the first scenario, the third scenario takes for granted the present government policy to control the utilisation of manure on land, and the intended policy to have all feedlot stables provided with biofiltration equipment after 15 years. The utilisation of manure on land is restricted by 10 % of the total amount of manure generated by the agricultural sector. The downward trend under the first scenario in both Alders and wet heathland is reversed, as can be seen in figures 4a-c. Costs of environmental policy cause the increase in value added - compared to the second scenario - to be lower. The total regional value added does not alter much in size, but in composition it does: costs of biofiltration are counterbalanced by the increase in recreational demand and timber production.

(4) **Land use shifts.**

This is based on the first scenario, but now the area allocated to arable land is reduced with 50% compared to 1980. The area of land allocated to forestry and natural vegetation increases with approximately 125%, with the exception of grassland area, the size of which is constant. The volumes of natural vegetation are significantly higher than under the first scenario (see figures 5a-c). Also due to less crop irrigation the stock of surface groundwater is higher, which has a positive effect on natural vegetation.

We summarize the results in the following conclusions:

a) The region is very sensitive to actions outside its boundaries, namely those causing SO2 and NOx to cross the boundaries; so supraregional agreements will be a prerequisite for a desirable development of this region.

b) Some of the regional activities show opposite effects to changes in the natural environment (agriculture against recreation and forestry), that sometimes may counterbalance one another (in terms of monetary economic benefits); however, the reactions of these activities may have different dynamic characteristics (slow - fast), so that the economic outcomes may vary significantly over longer periods of time.

The above model is clearly only a pilot model for RSD analysis, and further research is required to improve the empirical robustness of the model. Some equations require more reliable data to enable a realistic specification (e.g., recreational amenity, output from crops as a function of fertiliser and groundwater use). The model might also be validated by means of a historical run as a "backcasting" exercise. Other scenarios may be studied as well with extended versions of the model, such as changes in land use. Therefore, it is clear that the above results are for the time being mainly illustrative for RSD planning. Nevertheless, they have clearly demonstrated the validity of RSD modelling for policy analysis.

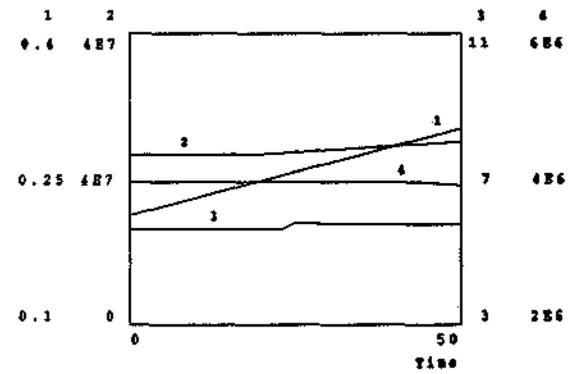

Figure 2a: Present development: Physical indicators.

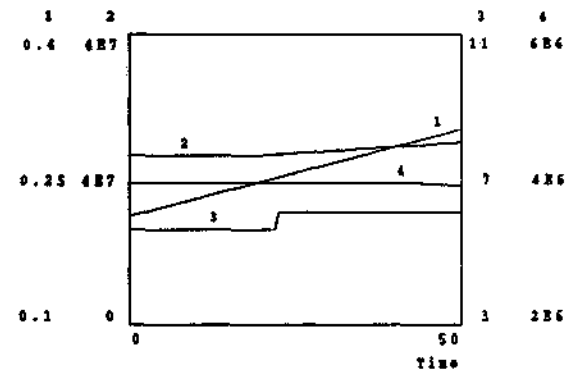

Figure 3a: No import of SO2 and NOx: Physical indicators.

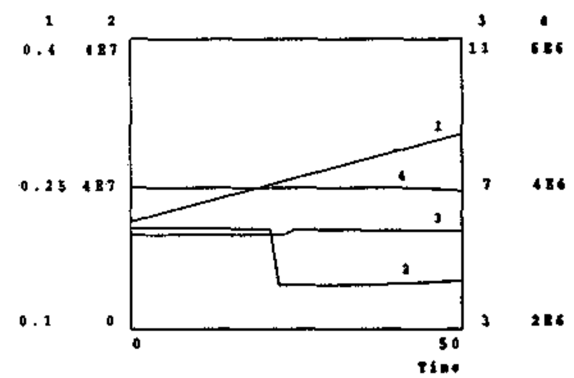

Figure 4a: Environmental policy: Physical indicators.

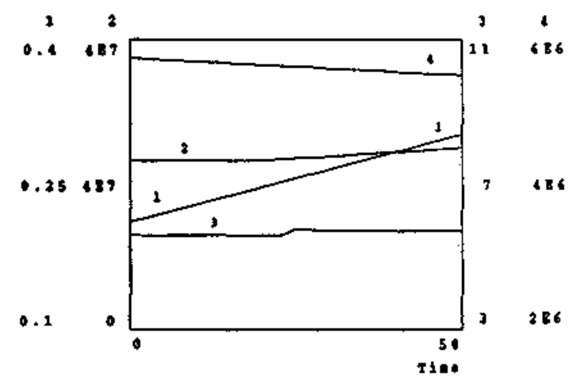

Figure 5a: Land use shifts: Physical indicators.

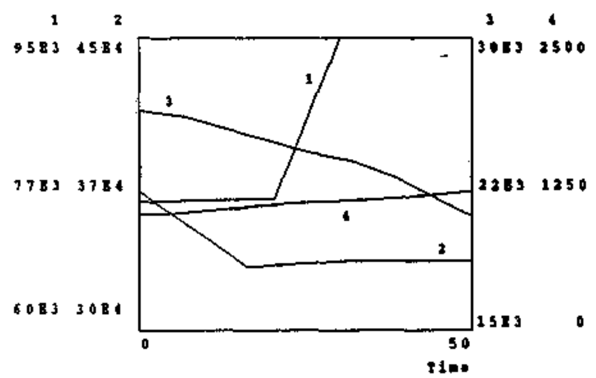

Figure 2b: Present development: Vegetational indicators.

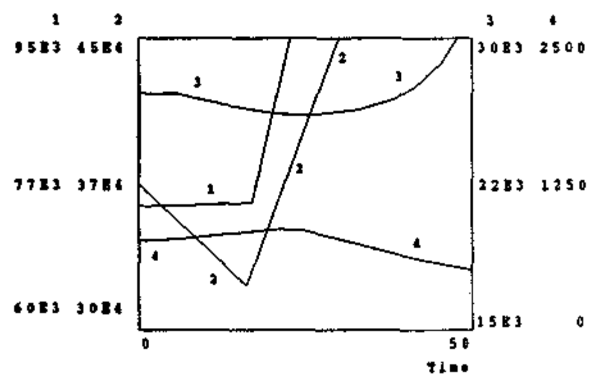

Figure 3b: No import of SO2 and NOx: Vegetational indicators.

LEGEND: Graphs a: *1=concentration of nitrates in deep groundwater; 2=the total ammonia release from manure; 3=the soil pH; 4=the volume of surface groundwater;* Graphs b: *1=stock of Alders; 2=stock of Douglas Pines; 3=stock of Wet Heathland; 4=stock of Grass.*

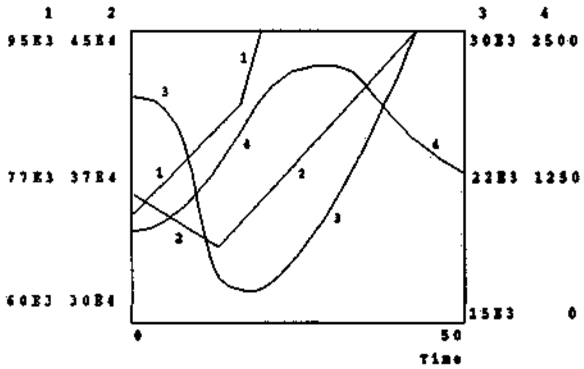

Figure 4b: Environmental policy: Vegetational indicators.

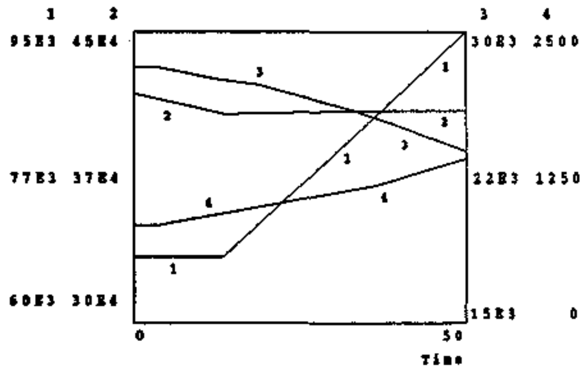

Figure 5b: Land use shifts: Vegetational indicators.

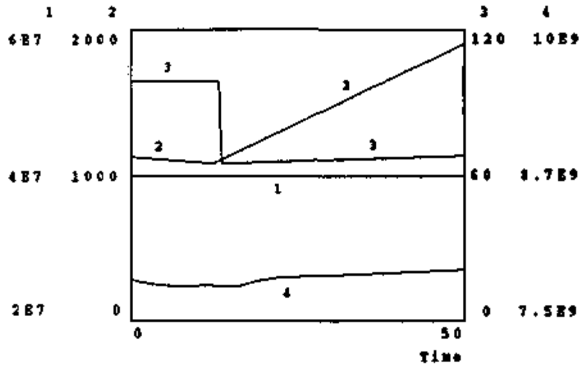

Figure 2c: Present development: Remaining indicators.

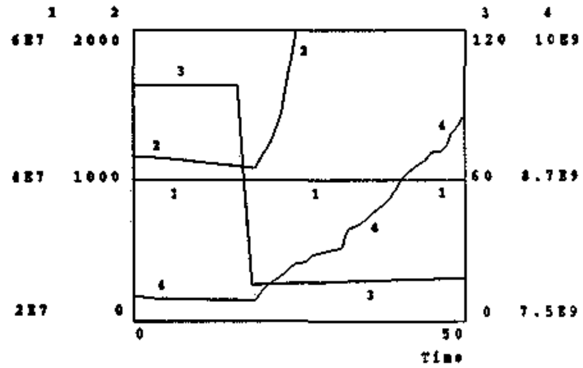

Figure 3c: No import of SO2 and NOx: Remaining indicators.

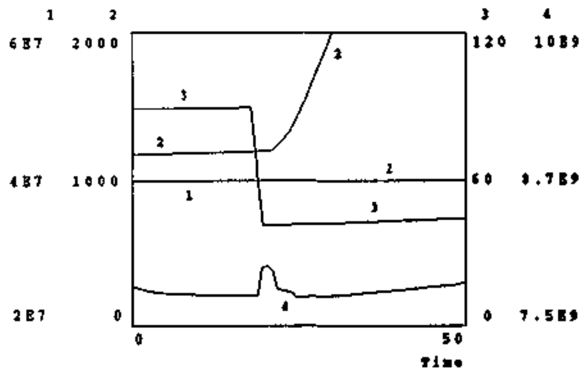

Figure 4c: Environmental policy: Remaining indicators.

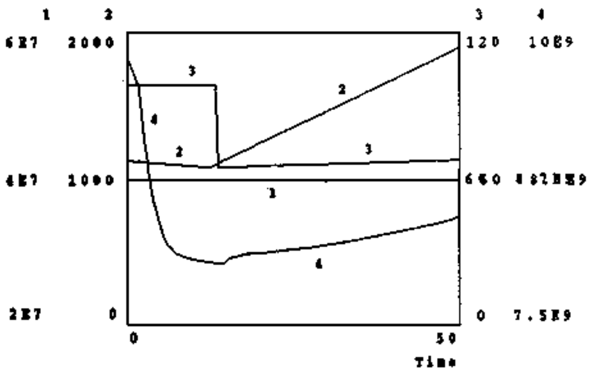

Figure 5c: Land use shifts: Remaining indicators.

LEGEND: Graphs b: *1=stock of Alders; 2=stock of Douglas Pines; 3=stock of Wet Heathland; 4=stock of Grass;* Graphs c: *1=the volume of deep groundwater; 2=the nature conservation value; 3=the air quality; 4=the total value added.*

6. CONCLUSIONS.

This paper has focused attention on sustainable development in a regional context. Conceptualizing and analyzing sustainable development is clearly not only important at a global level, but certainly also for a regional level of analysis and policy-making. Various advantages of a regional approach have been spelt out, in relation to regional causes and effects of environmental problems, the global character of economic processes, interregional interactions and the possibility of operationalizing SD on a regional scale. The use of models for studying sustainable development in a regional context was motivated while specific characteristics of such models were mentioned. Finally, a case study was presented in which some of the general discussions were illustrated, indicators for RSD were specified, and a descriptive systems model was developed. A set of scenarios was studied in which policies or developments were included that impact upon the region's economic-ecological interactions. The conclusions from these experiences are straightforward: modelling RSD in an operational way may substantially contribute to a better understanding of underlying conflicts in a regional development policy analysis.

ANNEX.

In this annex the model is outlined in more detail. The presentation here follows closely the style of the programming language Pascal. The modular structure of the model is reflected by the procedural structure in the following representation. We start here by giving the continuous variables - in brackets - a short circumscription of their meaning. For a more complete account of the model and the data we refer to van den Bergh et al. (1988).

Variables:

(* exogenous *)	Aa (area of arable land), Opp_A, Opp_P, Opp_Hw, Opp_Gr (areas with specific types of vegetation), On (imported NOx), SO2 (imported SO2), Sc (stock feedlot and grazing cattle), P (population);
(* management *)	P_M_wa (regulation price groundwater extraction by agriculture), M_N3, co_app (manure disposal rate on land), Mhp (harvest rate Pinus plantations);
(* stocks *)	Sg_surf, Sg_deep (ML volume of surface and deep groundwater stocks), Sn_soil, Sn_surf, Sn_deep (kg stocks of nitrate in soil, surface and deep groundwater), pH_soil (pH of soil, measure of soil acidification), S_A, S_P, S_Hw, S_Gr (m3/HA stock of Alders, pines, wet heathland and grass);
(* other *)	concN_surf, concN_deep (concentrations of nitrates in surface and deep groundwater), wa (water extraction by agriculture), outsurf (outflow surface groundwater to deep groundwater), wd (deep groundwater extraction for drinking water and industrial purposes), Nd_deep (natural net drainage out of deep groundwater), In_sgw (release of soil nitrate to surface groundwater), N3 (total ammonia release from manure), NH3 (Ammonia deposition per HA), Qair (an air quality index), NO3 (total nitrate release from manure), Vol_A, Vol_P, Vol_Hw, Vol_Gr (total volume in m3 of each type of vegetation), X_n (index of nature conservation), H_P (physical output harvest of pines), Addval_tot, Addval_Xa, Addval_Sc, Addval_wd, Addval_timber, Addval_Xo (added value of economic activities: total, recreation, cattle breeding, public utilities, forestry, and other, respectively), percapinc (per capital income), recharge (delayed inflow from surface to deep groundwater), Nout_surf (nitrate leaving surface groundwater with the groundwater flow);

```
PROCEDURE surfacegroundwater ( IN: P_M_wa,Aa,recharge,Sg_surf_0;
                               OUT: Sg_surf_1,wa,outsurf );
  VAR R,Ne;
  BEGIN
   R        := 675000 + wa;
   Ne       := 477000 + wa;
   wa       := 0.2*Aa*(1-0.2*P_M_wa);
   outsurf  := recharge;
   Sg_surf_1 := Sg_surf_0 + (R-Ne)/10 - wa - outsurf
  END; (* surface groundwater *)

PROCEDURE deepgroundwater (  IN: P,Sg_deep_0;
                             OUT: Sg_deep_1,recharge,wd,Nd_deep );
  BEGIN
   Nd_deep  := Sg_deep_0/4000;
   wd       := 0.06*P;
   IF recharge <= 15000 THEN recharge := wd + Nd_deep
                        ELSE recharge := 15000;
   Sg_deep_1 := Sg_deep_0 + recharge - wd - Nd_deep
  END; (* deep groundwater *)

PROCEDURE soilnitrate (  IN: On,SO2,NO3,NH3,Sn_soil_0,Qair;
```

```
                        OUT: Sn_soil_1,In_sgw,pH_soil );
  VAR In_NOx,In_atdep;
  BEGIN
   In_NOx     := 0.05*NO3;
   In_atdep   := 25000*( On/25 + NH3/10 + NH3*SO2/150 +1 );
   In_sgw     := 0.1*SQRT(Sn_soil_0);
   Sn_soil_1  := Sn_soil_0 + In_NOx + In_atdep - In_sgw - 0.15*Sn_soil_0
   pH_soil_1  := pH_soil - Qair/200 + MIN{0.25,-pH_soil/12}
  END; (* nitrates in soil *)

PROCEDURE surfacegroundwaternitrate ( IN: wa,outsurf,In_sgw,concN_surf,Sn_surf_0;
                                      OUT: Sn_surf_1,Nout_surf );
  VAR: Nout;
  BEGIN
   Nout_surf  := outsurf*concN_surf;
   Nout       := (20000 + wa)*concN_surf;
   Sn_surf_1  := Sn_surf_0 + In_sgw - Nout_surf - Nout
  END; (* nitrates in surface groundwater *)

PROCEDURE deepgroundwaternitrate ( IN: wd,Nd_deep,Nout_surf,concN_deep,Sn_deep_0;
                                   OUT: Sn_deep_1 );
  VAR: Out_Nd,Out_Nwd;
  BEGIN
   Out_Nd    := Nd_deep*concN_deep;
   Out_Nwd   := wd*concN_deep;
   Sn_deep_1 := Sn_deep_0 + Nout_surf - Out_Nd - Out_Nwd
  END; (* nitrates in deep groundwater *)

PROCEDURE ammoniaemisssion ( IN: co_app,M_N3,Sc,On,SO2;
                             OUT: N3,NH3,Qair);
  BEGIN
   N3   := (17/14)*( 1.2 + co_app + 0.95*(1-0.9*M_N3))*Sc;
   NH3  := N3/700000000;
   Qair := 5/( NH3/10 + On/25 + SO2/15 + On*SO2/375 + NH3*SO2/150)
  END; (* emissions ammonia *)

PROCEDURE nitrateemission (   IN: co_app,Sc;
                              OUT: NO3 );
  BEGIN
   NO3 := ( 1.32 + 6.66*co_app )*Sc
  END; (* nitremiss *)

PROCEDURE vegetation ( IN:Mhp,Opp_A,Opp_P,Opp_Hw,Opp_Gr,Sg_surf_1,Sn_soil_1,Qair,
                          S_A_0,S_P_0,S_Hw_0,S_Gr_0,pH_soil;
                       OUT: Vol_A,Vol_P,Vol_Hw,Vol_Gr,S_A_1,S_P_1,S_Hw_1,S_Gr_1,
                            Xr_veg, H_P );
  VAR: Gr_A,D_A,Gr_P,D_P,Gr_Hw,D_Hw,Gr_Gr,D_Gr;
  BEGIN
   Gr_A  := 0.05*S_A_0*Qair*Sg_surf_1/900000;
    D_A  := 0.06*S_A_0;
    S_A_1 := S_A_0 + Gr_A - D_A;
    Vol_A := Opp_A*S_A_1;
   Gr_P  := 0.14*S_P_0*Qair*5000/Sn_soil_1*pH_soil/6;
    D_P  := (0.007 + Mhp)*S_P_0;
    S_P_1 := S_P_0 + Gr_P - D_P;
    Vol_P := Opp_P*S_P_1;
```

```
    Gr_Hw  := 0.18*S_Hw_0*Sg_surf_1/Sn_soil_1;
     D_Hw   := 0.075*S_Hw_0;
     S_Hw_1 := S_Hw_0 + Gr_Hw - D_Hw;
     Vol_Hw := Opp_Hw*S_Hw_1;
    Gr_Gr  := 0.12*S_Gr_0*Sn_soil_1/Sg_surf_1;
     D_Gr   := 0.1*S_Gr_0;
     S_Gr_1 := S_Gr_0 + Gr_Gr - D_Gr;
     Vol_Gr := Opp_Gr*S_Gr_1;
    Xr_veg := (Vol_A + 1.5*Vol_P + Vol_Hw + Vol_Gr)/12618360.84;
    H_P    := Mhp*Opp_P*S_P_0
END; (* vegetation *)
```

```
PROCEDURE economicactivities ( IN:  disc_rate,M_N3,co_app,P_M_wa,Aa,Sc,wa,wd,NO3,H_P;
                               OUT: Addval_tot,Addval_Xa,Addval_Sc,Addval_wd,
                                    Addval_timber,Addval_Xo);
  VAR: m_out,Fert,Xa;
  BEGIN
    m_out      := 0.22*(1-co_app)*Sc;
    Addval_Sc := 0.4*(240 - 5.4*M_N3)*Sc - 18*m_out;
    Fert       := 0.5*NO3 + 450*Aa;
    Xa         := Aa*Fert*(1 - EXP(-0.001*wa))/207905750;
    Addval_Xa := 0.4*6100*Xa - P_M_wa*1000*wa;
    Addval_wd := 0.67*1000*wd;
    Addval_timber := 0.4*60*H_P;
    Addval_Xo := 6.4*1000*1000*1000;
    Addval_tot :=  Addval_Sc + Addval_Xa + Addval_wd + Addval_timber + Addval_Xo;
END; (* economic activities *)
```

The **initial conditions** are as follows:
sgsurf0= 4000000; sgdeep0= 6000000; snsoil0= 10000000; snsurf0= 88600000; sndeep0= 360000; concnsurf0= snsurf0/sgsurf0; pH_soil0=6; concndeep0= 25*sndeep0/sgdeep0;sa0 = 170; sp0= 1210; shw0= 10; sgr0= 10; recharge0[i]= 14247 (i= -10 to 0); noutsurf0[0]= 295000; noutsurf0[-1]= 265000; noutsurf0[-2]= 253333; noutsurf0[-3]= 225000; noutsurf0[-4]= 200000; noutsurf0[-5]= 148333; noutsurf0[-6]= 130000; noutsurf0[-7]= 66667; noutsurf0[-8]= 65000; noutsurf0[-9]= 62000; noutsurf0[-10]= 59000; noutsurf0[-11]= 58500; noutsurf0[-12]= 47333; noutsurf0[-13]= 35333; noutsurf0[-14]= 29500; noutsurf0[-15]= 23667; noutsurf0[-16]= 21000; noutsurf0[-17]= 17667; noutsurf0[-18]= 16150; noutsurf0[-19]= 14833; noutsurf0[-20]= 11833; noutsurf0[-21]= 10667; noutsurf0[-22]= 8333; noutsurf0[-23]= 6667.

The **structure of the dynamic model** based on the above set of modules is as follows:

```
 FOR time:=1 TO horizon DO
 BEGIN (* modelsimulationrun *)
   deepgrwater( exog[1,time],Sg_deep[time-1],Sg_deep[time],recharge[time],wd[time],
                Nd_deep[time] );
   surfgrwater(  exog[3,time],exog[2,time],recharge[time-10],Sg_surf[time-1],Sg_surf[time],wa[time],
                outsurf[time] );
   ammemiss( exog[8,time],exog[6,time],exog[9,time],exog[4,time],exog[5,time],N3[time],
                NH3[time],Qair[time] );
   nitremiss( exog[8,time],exog[9,time],NO3[time] );
   soilnitrate(  exog[4,time],exog[5,time],NO3[time],NH3[time],  Sn_soil[time-1],Sn_soil[time],
                In_sgw[time] );
   sfwatnitrate(    wa[time],outsurf[time],In_sgw[time],concN_surf[time-1],Sn_surf[time-1],
                Sn_surf[time], Nout_surf[time] );
   dpwatnitrate(  wd[time],Nd_deep[time],Nout_surf[time-23],concN_deep[time-1],
                Sn_deep[time-1],Sn_deep[time] );
   vegetation(  exog[7,time],exog[10,time],exog[11,time],exog[12,time],exog[13,time],
```

```
                    Sg_surf[time],Sn_soil[time],Qair[time],S_A[time-1],S_P[time-1],
                    S_Hw[time-1],S_Gr[time-1],Vol_A[time], Vol_P[time], Vol_Hw[time],
                    Vol_Gr[time], S_A[time],S_P[time],S_Hw[time],S_Gr[time], Xr_veg[time],
                    H_P[time] );
  econact(disc_rate,exog[6,time],exog[8,time],exog[3,time],exog[2,time],exog[9,time],wa[time],
         wd[time],NO3[time],H_P[time],Addval_tot[time],Addval_Xa[time], Addval_Sc[time],
         Addval_wd[time],Addval_timber[time],Addval_Xo[time] );
  concN_surf[time] := Sn_surf[time]/Sg_surf[time];
  concN_deep[time] := 25*Sn_deep[time]/Sg_deep[time];
  percapinc[time] := Addval_tot[time]/exog[1,time];
 END; (* modelsimulationrun *)
```

The **exogenous variables** are assigned values for each scenario. In the basic scenario the following values hold: P= 180000; Aa= 27700; P_M_wa= 0; On= 25; SO2= 15; M_N3= 0; Mhp= 0.02; co_app= 0.95; Sc= 2450000; Opp_A= 450; Opp_P= 7050; Opp_Hw= 3461; Opp_Gr= 2673;

REFERENCES.

Amstel, J. van, and Braat, L.C. (1989), Verdroging, Institute for Environmental Studies, Free University, Amsterdam

Archibugi, F. and P. Nijkamp (eds) (1989), Economy and ecology: towards sustainable development, Kluwer Nijhoff, Dordrecht

Barbier, E.B. (1989), Economics, natural resource scarcity and development: conventional and alternative views, Earthscan Publ., London

Bennett, R.J. and R.J. Chorley (1978), Environmental systems, Methuen&Co, London

Bergh, J.C.J.M. van den, and P. Nijkamp (1990), Operationalizing sustainable development: dynamic ecological economic models, Ecological Economics, 1991, forthcoming

Bergh, J.C.J.M. van den, and F.J. Soeteman (1990), Sustainable economic development of global and regional systems, Research Memorandum, Faculty of Economics, Free University, Amsterdam

Bergh, J.C.J.M. van den, L.C. Braat, A.J. Gilbert, D.E. James, G. Klaassen, F.J. Soeteman and I. Steetskamp (1988), Sustainable use of natural resources and economic development in the Peel, Interim report SPIDER research program, Institute for Environmental Studies and Department of Regional Economics, Free University, Amsterdam

Braat, L.C. and W.F.J. van Lierop (1987), Economic-ecological modeling, North-Holland

Briassoulis, H. (1986), Integrated economic-environmental-policy modeling at the regional and multiregional level: methodological characteristics and issues, Growth and Change 17, 22-34

Brouwer, F. (1987), Integrated environmental modelling: design and tools, Kluwer Academic Publishers, Dordrecht

Brouwer, F. and P. Nijkamp (1988), Design and structure analysis of integrated environmental planning models, European Review of Agricultural Economics 15, 1-38

Brown, B.J., et al (1987), Global sustainability: toward definition, Environmental Management 11, 713-719

Clark, C.W. (1976), Mathematical bioeconomics: the optimal management of renewable resources, Wiley-Interscience, New York

Clark, W.C. and R.E. Munn (1986), Sustainable development of the biosphere, Cambridge U.P., Cambridge

Collard,D., D.W. Pearce, and D. Ulph (eds.) (1988), Economics, growth and sustainable environments, St. Martin's Press, New York

Daly, H.E. (1990), Toward some operational principles of sustainable development, Ecological Economics 2, 1-6

Frenkiel, F.N. and D.W. Goodall (eds.) (1978), Simulation modelling of environmental problems, Wiley, N.Y.

Goodland, R. and G. Ledec (1987), Neoclassical economics and principles of sustainable development, Ecological Modelling 38, 19-46

Guetzkow, H., P. Kotler and R.L. Schultz (eds.) (1972), Simulation in social and administrative science: overviews and case-examples, Prentice-Hall, Englewood Cliffs, N.J.

Holling, C.S. (ed.) (1978), Adaptive environmental assessment and management, Wiley, New York

Howe, C.W. (1979), Natural resource economics: issues, analysis and policy, Wiley

Howe, C.W. (1987), On the theory of optimal regional development based on an exhaustible resource, Growth and Change 18, 53-68

Hueting, R. (1990), The Brundtland report: a matter of conflicting goals, Ecological Economics 2, 109-117

Isard, W. (1972), Ecologic-economic analysis for regional development, The Free Press, New York

Kamien, M.I. and N.L. Schwartz (1982), The role of common property resources in

optimal planning models with exhaustible resources, in: V.K. Smith and J.V. Krutilla (eds), Explorations in natural resource economics, Johns Hopkins University Press, Baltimore
Leontief, W.W. and D. Ford (1972), Air pollution and the economic structure, in A. Brody and A.P. Carter (Eds.), Input-output techniques, North-Holland, Amsterdam
Lonergan, S.C. (1981), A methodological framework for resolving ecological/economic problems, Papers of the Regional Science Association 3, 117-134
Meadows, D.H., J. Richardson and G. Bruckmann (1982), Groping in the dark: The first decade of global modeling, Wiley, NY
Miernyk, W.H. (1982), Regional analysis and regional policy, Oelgeschlager, Gunn and Hain, Cambridge Mass.
NAVF (1990), Sustainable development, science and policy, Conference Report Norwegian Research Council for Science and the Humanities, Oslo
Neary, J.P. and S. van Wijnbergen (1985), Natural resources and the macroeconomy, Basil Blackwell, Oxford
Nijkamp, P., P. Rietveld and H. Voogd (1990), Multicriteria Evaluation in Physical Planning, North-Holland, Amsterdam
Odum, H.T. (1987), Models for national, international, and global systems policy, in: L.C. Braat and W.F.J. van Lierop (eds.), Economic-ecological modeling, North-Holland
Opschoor, J.B. (1987), Duurzaamheid en verandering: over ecologische inpasbaarheid van economische ontwikkelingen (Sustainability and change), Inaugural Address, Free University, Amsterdam (in Dutch)
Patten, B.C. (ed.), Systems analysis and simulation in ecology, Volumes I-IV, Academic Press 1971
Pezzey, J. (1989), Economic analysis of sustainable growth and sustainable development, Environmental Department Working paper no.15, Environmental Department, The World Bank.
Redclift, M. (1987), Sustainable development: exploring the contradictions., Methuen, London
Richmond, B. et al., (1987), STELLA userguide, Dartmouth College, Lyme, New Hampshire
Siebert, H. (1969), Regional economic growth: theory and policy, International Textbook Co., Pennsylvania
Siebert, H. (ed.) (1984), The resource sector in an open economy, Springer-Verlag
Simonis, U.E. (1990), Beyond growth: elements of sustainable development, Edition Sigma, Berlin
The World Commission on Environment and Development (WCED) (1987), Our common future, Oxford University Press, Oxford
Tolba, M.K. (1987), Sustainable development: constraints and opportunities, Butterworths, London
Turner, R.K. (1988) (ed.), Sustainable environmental management: principles and practice, Belhaven Press, London
Vincent, D.P. (1982), The ORANI approach to quantitative modelling of the Australian agricultural sector, European Review of Agricultural Economics 9, 415-442
Walker, R. (1987), Regional development and renewable resource exploitation, Ecological Modelling 37, 303-316
Walters, C.J. (1986), Adaptive management of renewable resources, Macmillan
Vries, H.J.M. de (1989), Sustainable resource use: an enquiry into modelling and planning, University Press, Groningen

1990-1	B. Vogelvang	Testing For Co-Integration with Spot Prices of Some Related Agricultural Commodities
1990-2	J.C.J.M. van den Bergh P. Nijkamp	Ecologically Sustainable Economic Development Concepts and Model Implications
1990-3	J.C.J.M. van den Bergh P. Nijkamp	Ecologically Sustainable Economic Development in a Regional System: A Case Study in Agri cultural Development Planning in the Netherlands
1990-4	C.Gorter P.Nijkamp P.Rietveld	Employers' Recruitment Behaviour and Re-Employment Probabilities of Unemployed
1990-5	K.Burger	Off-farm income and the farm-household the case of Kenyan smallholders
1990-6	H. Visser	Crowding out and the Government Budget
1990-7	P. Rietveld	Ordinal Data in Multicriteria Decision Making, a Stochastic Dominance Approach to Siting Nuclear Power Plants
1990-8	G. van der Laan P.H.M. Ruys D.J.J. Talman	Signaling devices for the supply of semi-public goods
1990-9	F.A.G. den Butter	Labour Productivity Slowdown and Technical Progress: An empirical analysis for The Netherlands
1990-10	R.W. van Zijp	Neo-Austrian Business Cycle Theory
1990-11	J.C. van Ours	Matching Unemployment and Vacancies: The Efficiency of the Dutch Labour Market
1990-12	B. Vogelvang	Hypotheses Testing Concerning Relationships between Spot Prices of Various Types of Coffee
1990-13	A.F. de Vos I.J. Steyn	Stochastic Nonlinearity: A Firm Basis for the Flexible Functional Form
1990-14	Y.H. van Emmerik D. de Jong W.W.A. Zuurmond D.N. Dukkers-van Emden	Opereren in overleg: geprotocolleerde samenwerking 1e-2e-lijn bij dagchirurgie
1990-15	T.J.J.B. Wolters	Mediation and Collective Bargaining: A Diagnostic Approach
1990-16	E.M.A. Scholten J. Koelewijn	Financieringsproblematiek van startende ondernemingen: een mogelijke verklaring op basis van empirisch onderzoek.
1990-17	E. Hüner H.P. Smit	Saturation and Model Specification of Passen ger car Ownership
1990-18	F.A.G. den Butter	Sociale zekerheid, de wig en economische groei